# SECTION 14—POWER SYSTEMS TECHNOLOGY



***OVERVIEW***

Electric power drives subsystems and systems in literally hundreds of kinds of U.S. military equipment. These many ongoing applications dictate military requirements for power level, power reliability, ruggedness, packaging and ability to operate in a wide range of environments. At the same time, a dual-use revolution is in progress which makes electric power the source of choice for applications which have belonged to hydraulic, pneumatic or other kinds of energy sources in the past. Technically, improvements in electric power are characterized by the ability to get more work per unit of input, more precise control and application of power to each task assigned, and greater military capability through improvements in performance and reliability, increased compactness and lower costs of ownership. Power systems can be organized in many ways. This section first covers **high density conventional systems**. These systems are packaged for military operations, but encompass a power range which is populated by literally thousands of commercial items and technical approaches. Features distinguishing military criticality are taken from the traits required by the military, but only desired in commercial applications. The power range of these systems is from 0 to 500 kilowatts, which is the upper level of commonly used commercial systems. The third section covers **pulsed and high power systems**, which are generally found infrequently in commercial applications because the military weight and size constraints simply do not apply to commercial needs. These systems have power levels in excess of 500 kilowatts. **Mobile electric platform power** applies a suite of technologies so that electric power can function as a multipurpose and single source of energy that combines propulsion of the mobile platform with operation of the systems mounted on that platform.

# SECTION 14.1—HIGH DENSITY CONVENTIONAL SYSTEMS

***OVERVIEW***

This section covers power systems comprising components/subsystems rated at less than 500 kilowatts. Such systems are found in almost every military operating system, including multiple components of major weapons. Critical technologies in this section cover both power sources and power conditioning activities. Power systems are fundamental components which are often specifically tailored for each of the other major technology areas within the MCTL.

**Table 14.1-1. High Density Conventional Systems Militarily Critical Technology Parameters**

| TECHNOLOGY | Militarily Critical Parameters Minimum Level to Assure US Superiority | Critical Materials | Unique Test, Production, and Inspection Equipment | Unique Software and Parameters | Control Regimes |
|---|---|---|---|---|---|
| **ELECTRICAL MACHINES (INCLUDES GENERATORS, STARTER/GENERATOR AND ACTUATORS)** | Power Density > 5 kW/kg<br>High Temperature<br>> 200 °C environment<br>At operating frequencies (systems dependent) | None identified | None identified | None identified | None |
| **INSULATION SYSTEM** | Temperature > 300 °C<br>Long life > 25,000 hours; at 400 V/µm (10 kV/mil) | Polymers, ceramics, inorganics, liquids and mixtures used to achieve militarily critical parameters | None identified | None identified | None |
| **RESERVE BATTERIES** | Density > 350 W-hr/kg over range 350 °C to 500 °C | High temperature materials for electrodes, separators, electrolytes, containers | None identified | None identified | WA IL Cat 3 |
| **PRIMARY BATTERIES** | Density > 120 W-hr/kg over range - 30 °C to + 70 °C | None identified | None identified | None identified | WA IL Cat 3 |
| **RECHARGEABLE BATTERIES** | Bipolar designs > 270 volts, > 1000 cycles;<br>Lithium polymer technology > 200 Whr/kg and > 1000 cycles;<br>Lithium ion batteries<br>> 180 Whr/kg and<br>> 1000 cycles | Materials for seals or seal technology, high conductivity polymer electrolyte, high energy density anode/cathode | None identified | None identified | None |
| **POWER SEMICONDUCTORS** | High current density<br>> 500 A/cm$^2$<br>> 300 °C junction temperature<br>High switching frequency:<br>> 100 kHz below 10 kW,<br>> 500 kHz above 10 kW<br>Blocking voltage > 600 V | High temperature materials: gallium nitride, titanium, inorganic insulators, aluminum nitride, silicon nitride, silicon carbide | Surface mount technology<br>Electro-deposition process<br>Ultrasonic bonding | None identified | WA ML 19 |

(Continued)

**Table 14.1-1. High Density Conventional Systems Militarily Critical Technology Parameters (Continued)**

| TECHNOLOGY | Militarily Critical Parameters Minimum Level to Assure US Superiority | Critical Materials | Unique Test, Production, and Inspection Equipment | Unique Software and Parameters | Control Regimes |
|---|---|---|---|---|---|
| **CAPACITORS**<br>- **FILTER**<br>- **ENERGY STORAGE** | Filter: > 200 °C; ESR < 0.5 milliohms - Energy density. > 1.5 J/g electrostatic capacitor Energy Storage: energy density > 40 J/g for electrochemical energy storage capacitors; ESR < 5 milliohm over –55 °C to 80 °C Voltage > 600 V | Dielectrics: impregnants, polymer, ceramics, inorganics and mixtures | Winding machines | None identified | None |
| **CAPACITOR DIELECTRIC MATERIAL** | Filter: Case 1: breakdown strength > 10 kV/mil, temp > 200 °C, dielectric constant > 3, dissipation factor < 0.0002 Energy Storage: Case 2: breakdown strength > 140 V/µm (3 kV/mil), temp > 300 °C, dielectric constant > 10, dissipation factor < 0.0005 | polymer, ceramics, inorganics and mixtures | None identified | None identified | None |

## SECTION 14.2—MOBILE ELECTRIC PLATFORM POWER

***OVERVIEW***

Mobile electric platform power systems combine the propulsion and electrical energy generation functions. One example is provided in graphic form in Fig. 14.2-1. This illustrates thinking about how platform power is generated, stored, managed and used, using components as indicated. The net effect, through advances in technologies, is a power system which has operational advantages of: reduced signature, increased density, lower weight and volume, greater flexibility in configuration and greater economy/reliability. Power components are characterized by significant reduction in moving parts, elimination of rigid connections and improved ability to use small and irregular spaces within a vehicle.

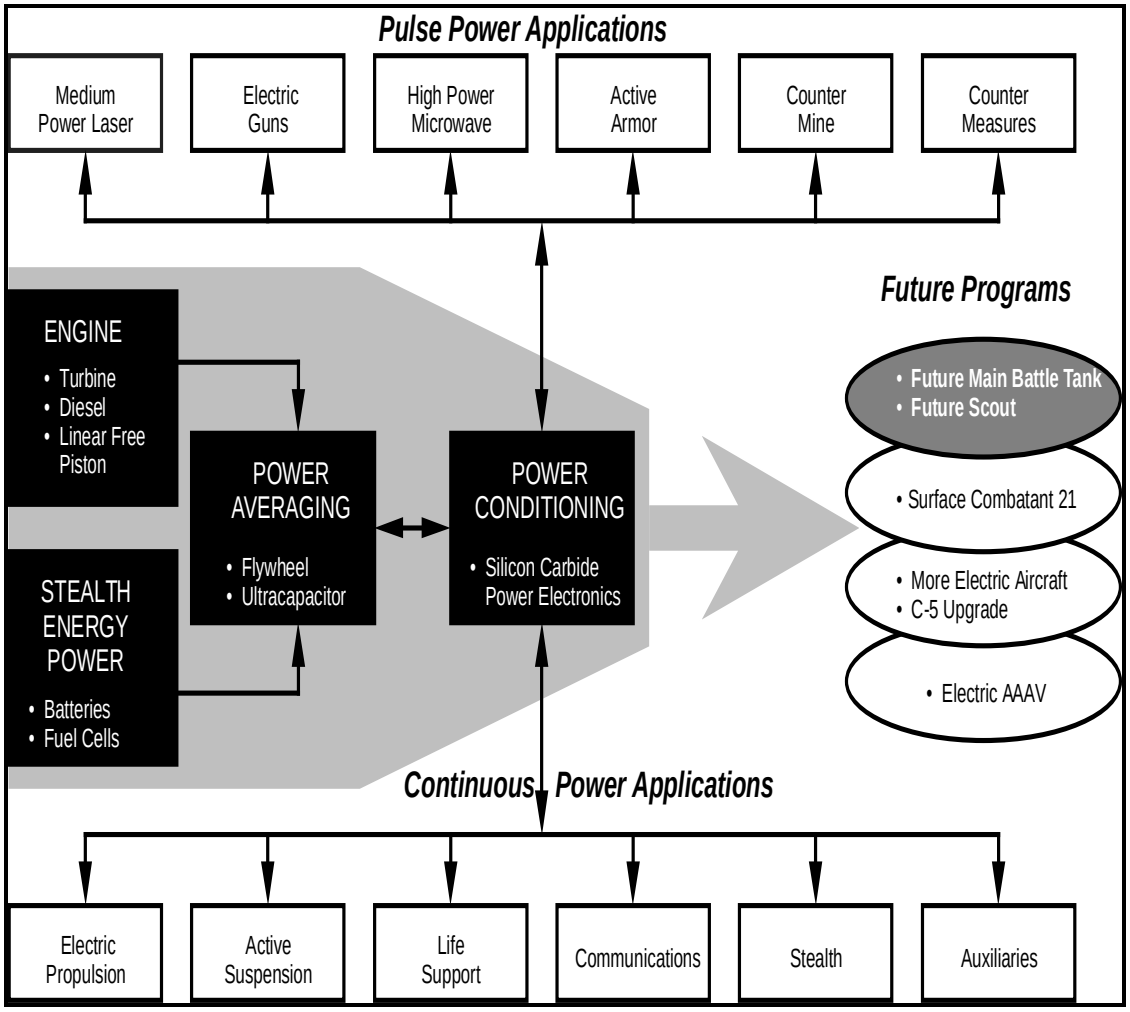


**Figure 14.2-1. Integrated Mobile Electric Platform Power System**

**Table 14.2-1. Mobile Electric Platform Power Militarily Critical Technology Parameters**

| Technology | Militarily Critical Parameters Minimum Level to Assure US Superiority | Critical Materials | Unique Test, Production, and Inspection Equipment | Unique Software and Parameters | Control Regimes |
|---|---|---|---|---|---|
| **Power Semiconductor Devices (e.g., SiC Technology for closing/opening active switches)** | > 300 °C operating temp,<br>> 1500 V<br>500 amp/cm$^2$ | High temperature materials: gallium nitride, silicon carbide aluminum nitride, inorganic insulators | Manufacturing equipment for e.g., crystal growth, epitaxial deposition and ion implantation | None identified | None |
| **Chemical Double Layer Capacitor Technology for energy storage and filtering** | > 5 kWh, >1000 V,<br>> 20 Wh/kg | Not included | Electrode production line which provides high volume continuous production. Cell fabrication equipment; high power discharge equipment; layer uniformity, planarity inspection equipment | None identified | WA IL Cat 3 |
| **Permanent Magnet Materials Technology** | > 300 °C operating temp,<br>> 50 mega gauss-oersted | Magnetic metals and materials | Electrode production line which provides high volume continuous production. Cell fabrication equipment; High power discharge equipment; layer uniformity, planarity inspection equipment | None identified | WA IL Cat 3 |
| **High Power Rotating Machines** | Power density > 200 W/kg<br>tip speed > 300 m/s | Ferromagnetic composites for rotors insulation coordination/ materials | Equipment for balancing rotating machinery of mass > 1000 kg at speeds > 2500 RPM; test equipment to simulate stress in structure, mechanical and electromechanical design | None identified | WA ML 12, 19 |
| **Advanced Switching Topologies including Soft Switching Technologies** | >30 mW/m$^3$ > 70 kHz<br>> 0.5 mW average power | None identified | None identified | None identified | WA ML 19 |
| **Flywheel (High Energy Density) Technology** | >150 kJ/kg, > 6 kW/kg: Energy extraction in seconds of > 500 MJ/m$^3$ | Composites | None identified | None identified | WA ML 18, 22 |

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**Table 14.2-1. Mobile Electric Platform Power Militarily Critical Technology Parameters (Continued)**

| TECHNOLOGY | Militarily Critical Parameters Minimum Level to Assure US Superiority | Critical Materials | Unique Test, Production, and Inspection Equipment | Unique Software and Parameters | Control Regimes |
|---|---|---|---|---|---|
| **BATTERY TECHNOLOGY** | > 75 kJ/kg, > 3 kW/kg after 75 charge/discharge cycles to an 80% depth; recharge in 100–300 seconds | Multiple materials for electrodes, separators, electrolytes | None identified | None identified | WA IL Cat 3 |
| **MOTOR CONTROL INVERTERS** | Power density > 30 MW/$m^3$ at $P_{av}$ > 200 kW | Composites, magnetics, insulators and other materials that enable high power density systems | Integration and testing | None identified | None |

# SECTION 14.3—PULSED AND HIGH POWER SYSTEMS

***OVERVIEW***

High power electronics consists of a system for conversion of prime electrical power into the necessary short pulses of electrical energy needed to energize loads such as directed energy and kinetic energy weapons, and high power microwaves. These technologies are applied to both weapons and sensors of many kinds. Peak power, pulse shape, pulse duration, repetition rates, firing rates, silent watch, and system energy storage recharging times all represent militarily critical performance parameters that transcend known commercial, industrial, or consumer applications. In addition, high power electronics packaging currently requires parallel/series combinations of components in the power train to achieve reliability, fault tolerance, and graceful aging at performance levels far higher than today's commercial standards.

**Table 14.3-1. Pulsed and High Power Systems Militarily Critical Technology Parameters**

| TECHNOLOGY | Militarily Critical Parameters Minimum Level to Assure US Superiority | Critical Materials | Unique Test, Production, and Inspection Equipment | Unique Software and Parameters | Control Regimes |
|---|---|---|---|---|---|
| **HIGH POWER ELECTRONICS - CONTINUOUS (CW) (TOP PARAMETERS DESCRIBED)** | Density > 25 $mW/m^3$ at $P_{av}$ > 0.5 $mW_{avg}$ | Composites | None identified | Power management and control systems | None |
| **HIGH POWER ELECTRONICS - PULSED (TOP PARAMETERS DESCRIBED)** | > 5 x $10^9$W peak<br>>1 $MJ/m^3$<br>> 1 $MW_{avg}$ at any operational repetition rate | Composites | Test equipment for pulse diagnostics and component and material manufacturing | Phased triggering for series/ parallel switching components | None |
| **BATTERIES: PRIMARY AND RESERVE** | Temperature range: -30 °C to 70 °C; > 10 MJ per kg; >70 MJ per $m^3$<br>150 Wh/kg after 75 charge/discharge cycles at a discharge current equal to C/5 hours (C being the nominal capacity in ampere hours) | None identified | Material processing and for purity and uniformity<br>Test equipment for pulse diagnostics<br>Environmental compatibility | None identified | WA IL Cat 3<br>MTCR |
| **CAPACITORS** | > 1.5 kJ/kg, > 5 kV<br>prf > 0.2 Hz: graceful aging<br>< ms discharge time<br>> 80% charge/discharge efficiency | Selected ceramics, polymers | Equipment to make and validate material free of defects having uniform thickness; metallized electrodes and connections at high current densities | None identified | WA IL Cat 3<br>MTCR |
| **SOLID STATE SWITCHES FOR HIGH POWER ELECTRONICS** | > 500 $A/cm^2$<br>> 5 kV, 1–5 ms pulses,<br>> 1 mA, prf to 10 Hz<br>> 100 kV, 1 µs pulses,<br>> 100 mW, > 10 kA/µs<br>> 1 kJ, prf > 1 kHz<br>> 5 kV, CW, > 70 kHz, 1 kA | Silicon carbide | Purity of substrate materials/device design/processing and packaging | None identified | WA ML 19 |

(Continued)

**Table 14.3-1. Pulsed and High Power Systems Militarily Critical Technology Parameters (Continued)**

| TECHNOLOGY | Militarily Critical Parameters Minimum Level to Assure US Superiority | Critical Materials | Unique Test, Production, and Inspection Equipment | Unique Software and Parameters | Control Regimes |
|---|---|---|---|---|---|
| **PULSE TRANSFORMERS** | Operating at > 500 kV at 1–10 kJ/pulse, at a repetition rate > 100 Hz | Pulsed insulations and low dielectric constant and lower loss MHz class ferrites | Quality processing and validation for leakage inductance/capacitance/insulation and insulation strength | None identified | WA ML 19 |
| **POWER DISTRIBUTION/ MANAGEMENT ARCHITECTURE** | > 5 kV, 1–25 $mW_{avg}$ Power Quality: THD < 1%, Voltage regulation < 0.1% in mobile configurations | Conductors and insulators which take thermal stress | Quality processing and validation for leakage inductance/capacitance/insulation and insulation strength | Power Management and Control Systems | None |
| **PRIME POWER SYSTEMS: INCORPORATING CW AND PULSED ALTERNATORS** | $P_{av}$ > 1 mW<br>1 $GW/m^3$<br>1 ms pulse duration<br>> 10 MJ/pulse | High strength composites mechanical impulse-toughened, insulation, ceramic and magnetic bearings | Impregnation & winding equipment/NDI test equipment | None identified | None |
| **PRIME POWER SYSTEMS: ROTATING ELECTROMAGNETIC COMPULSATORS** | Specially designed for repetitive burst operations (2 or more pulses) at energy levels<br>> 10 MJ/pulse | High strength composites Mechanical impulse-toughened, insulation Ceramic and magnetic bearings | Impregnation and winding equipment/NDI test equipment | None identified | None |